An Analysis of Cool Season Synoptic High Wind Events on Lake Superior

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Outline

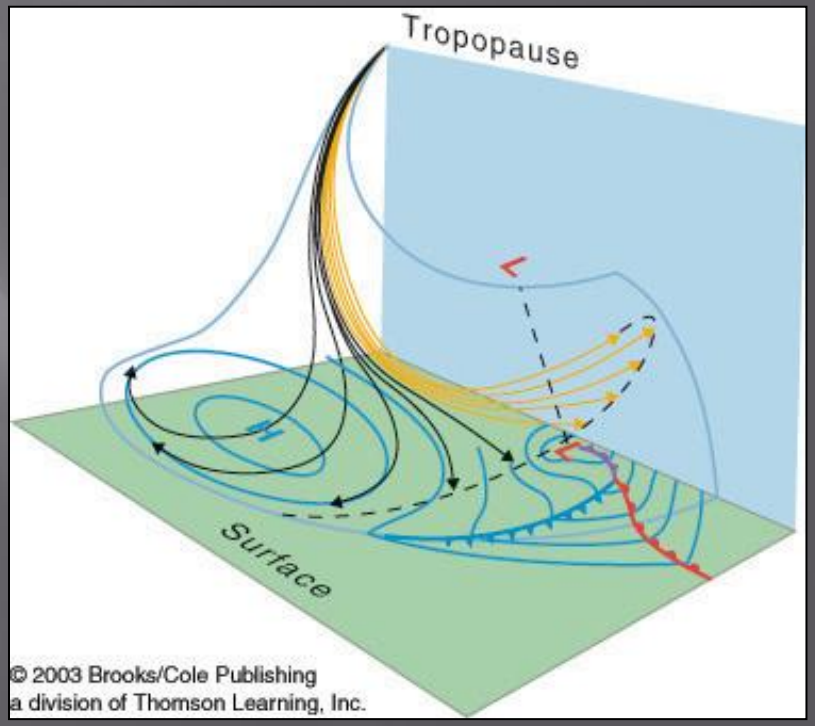
- Literature review and forecasting methods of non-convective high wind events (NCHWs)
- High wind climatology for Lake Superior
- Detailed analysis of the anomalous September 29th-30th, 2011 event
- A few conclusions

Literature Review

- Kapela et al. (1995)
  - Forecasting NCHWs
- Niziol and Paone (2000)
  - High wind climatology for western New York
- Lacke et al. (2007)
  - Climatology of cool season Great Lakes high wind events
- Other climate and case studies (Knox, Richwien, Hultquist et al., Crupi, etc.)

Post Cold Front High Wind Checklist from Kapela et al. (1995)

- Subsidence
  - Strong 500mb vorticity maximum to the north and east
  - Deep, strong CAA
  - Dry slot signature on water vapor imagery
- Weak static stability
  - Stratospheric intrusion
  - High low-level lapse rates
- Strong isallobaric gradient aiding geostrophic wind
  - Isallobars perpendicular to isobars
- Minimal directional wind shear

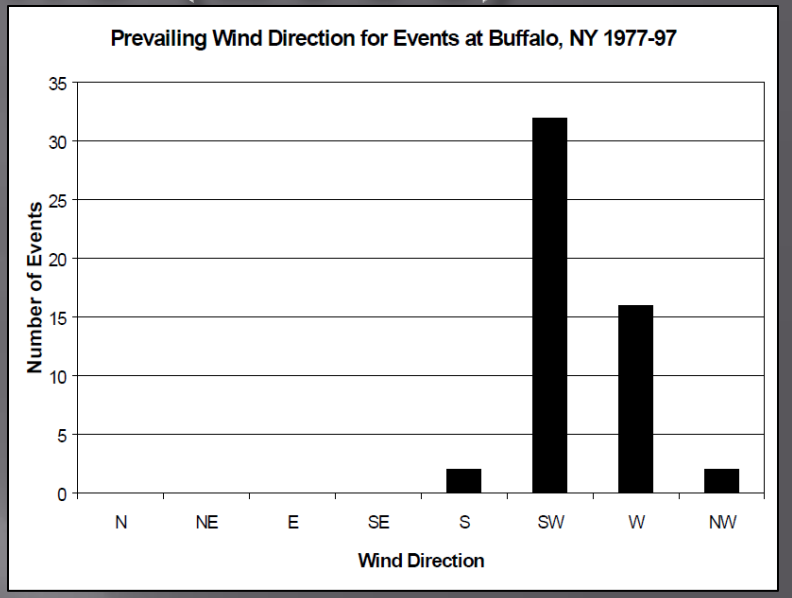


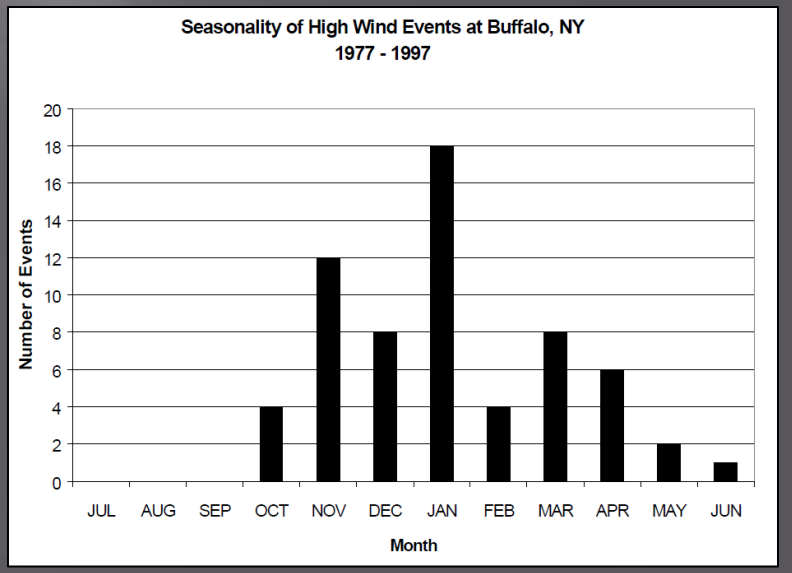
Other features that may aid the development of NCHWs

- **Strong surface geostrophic wind**
  - **Good estimate of maximum surface winds (could underestimate the maximum wind potential)**
- **Evaporative cooling aloft**
  - **Steepens low-level lapse rates**
- **Mixing from shallow convection**
  - **Aides downward momentum transfer**

Niziol and Paone (2000)

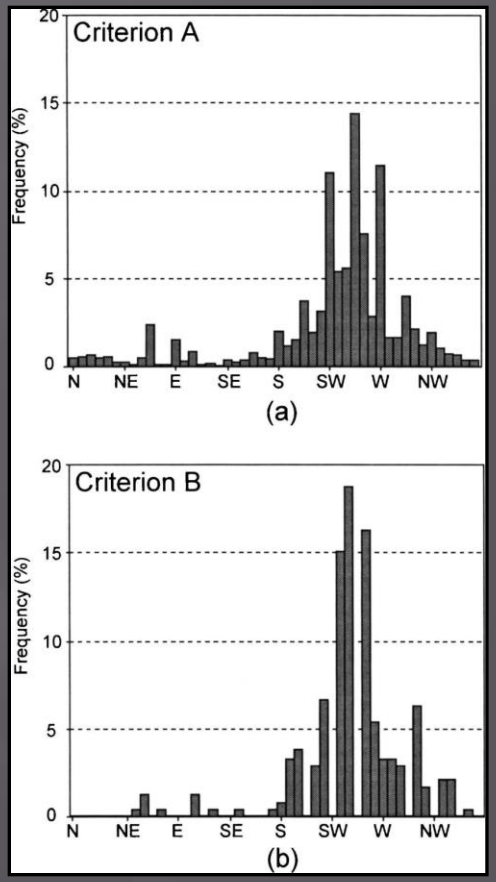
- Analyzed 52 high wind events over 20 years for western New York using wind gusts ≥ 50kts at Buffalo
- Favored direction was from the southwest to west
- Most common from late fall to early spring
- Emphasized CAA, low-level lapse rates, and isallobaric wind



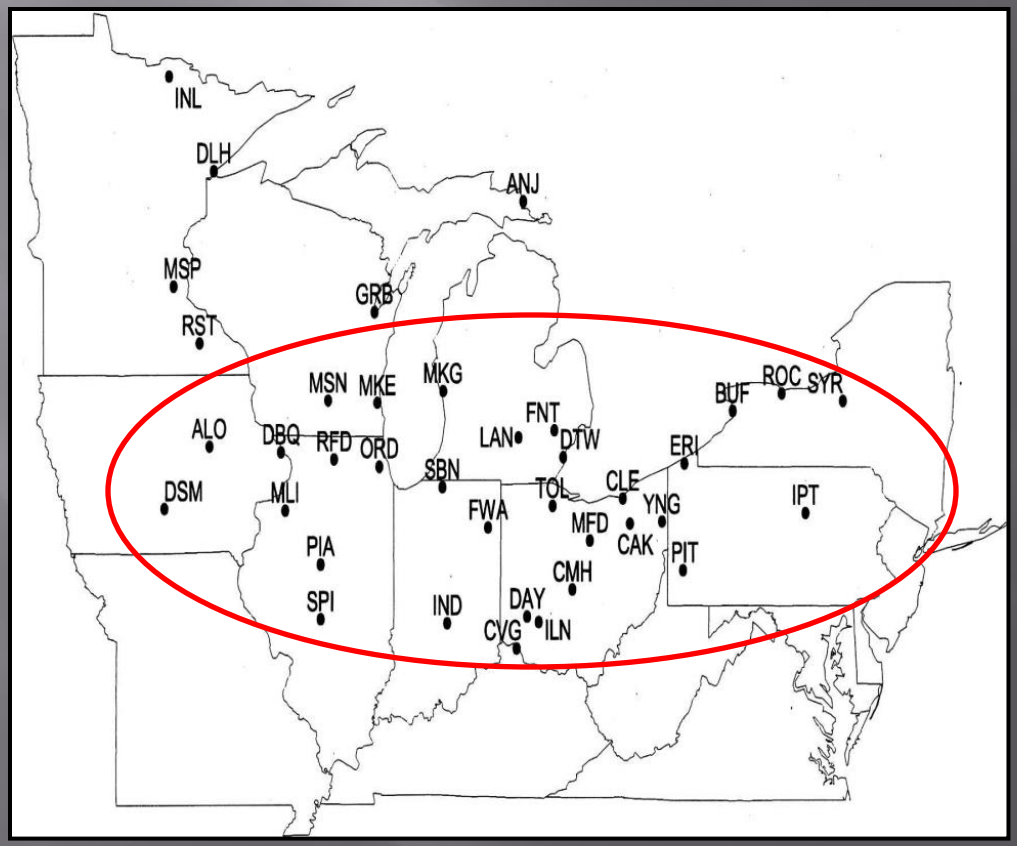


Lacke et al. (2007)

- Analyzed 38 sites using 44 years of November to April data
  - Criterion A: Sustained wind speed ≥ 35kts for at least 1 hour
  - Criterion B: Any wind gust ≥ 50kts
- Favored direction (75%): SW quadrant – specifically WSW
- At least 60% of the events occurred from January to April

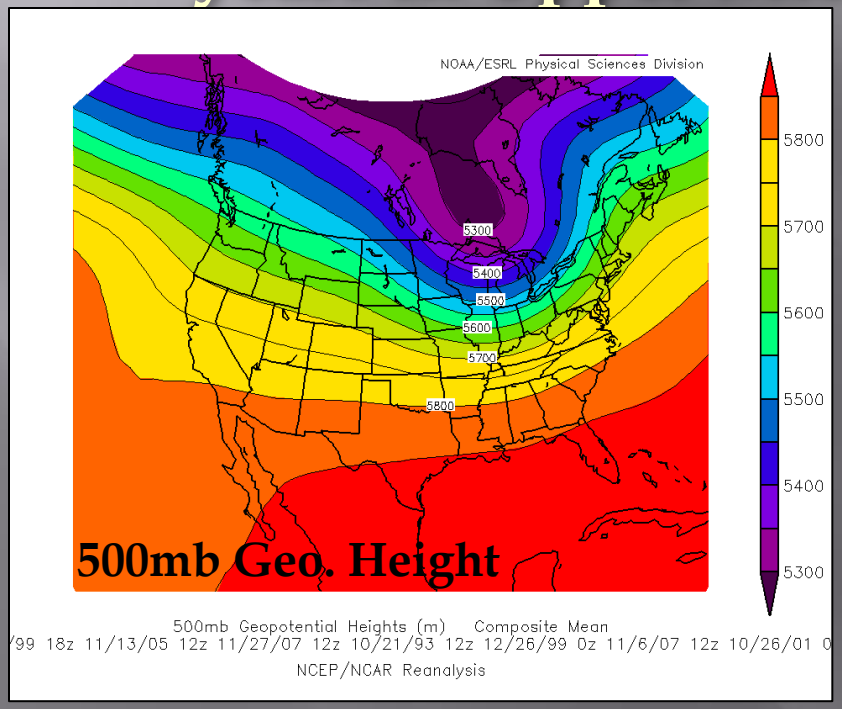


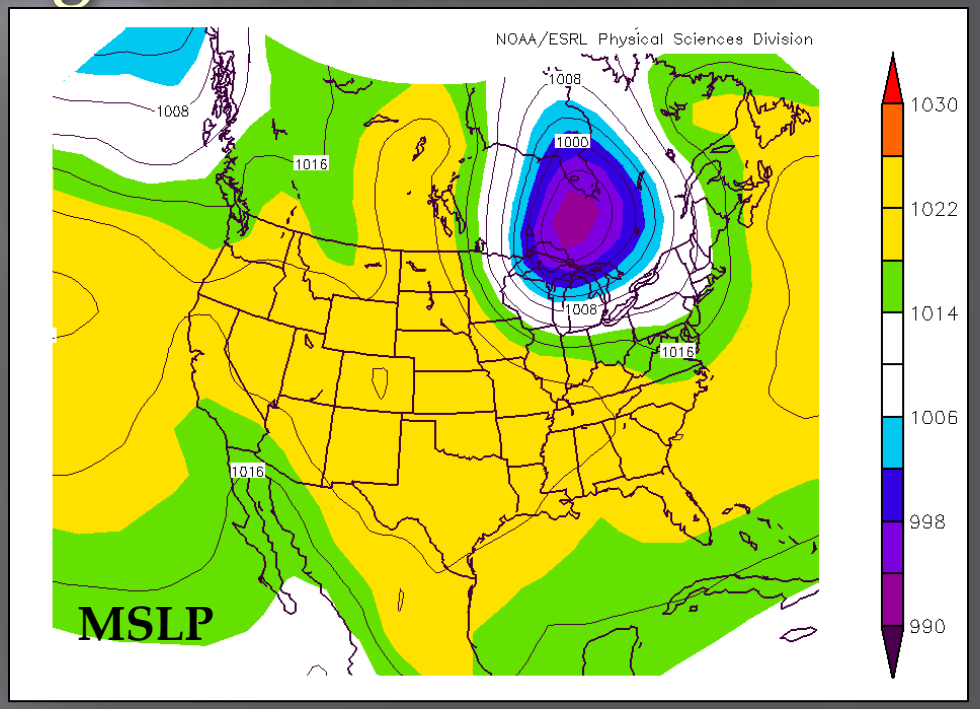
- Nearly 80% of the stations used in the study were from the southern half of the Great Lakes
  - Less land-based observations across the north
- For Rochester, MN, the prevailing high wind direction was west to northwest



Composite Charts for Upper Michigan High Wind Events

- To quantify some of the results from Kapela et al. and Niziol and Paone, some composite charts for high wind events over the last 20 years in Upper Michigan were constructed



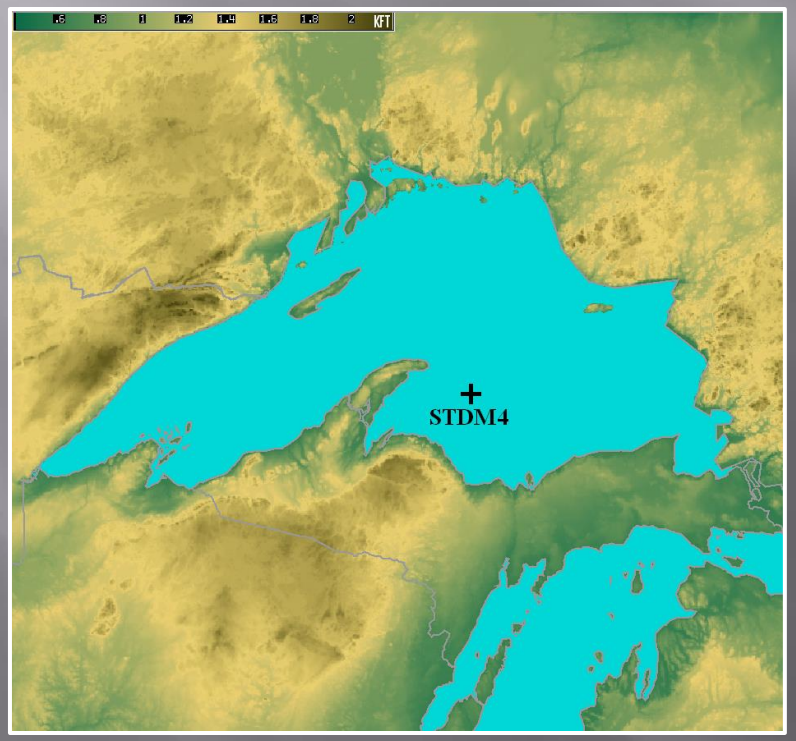


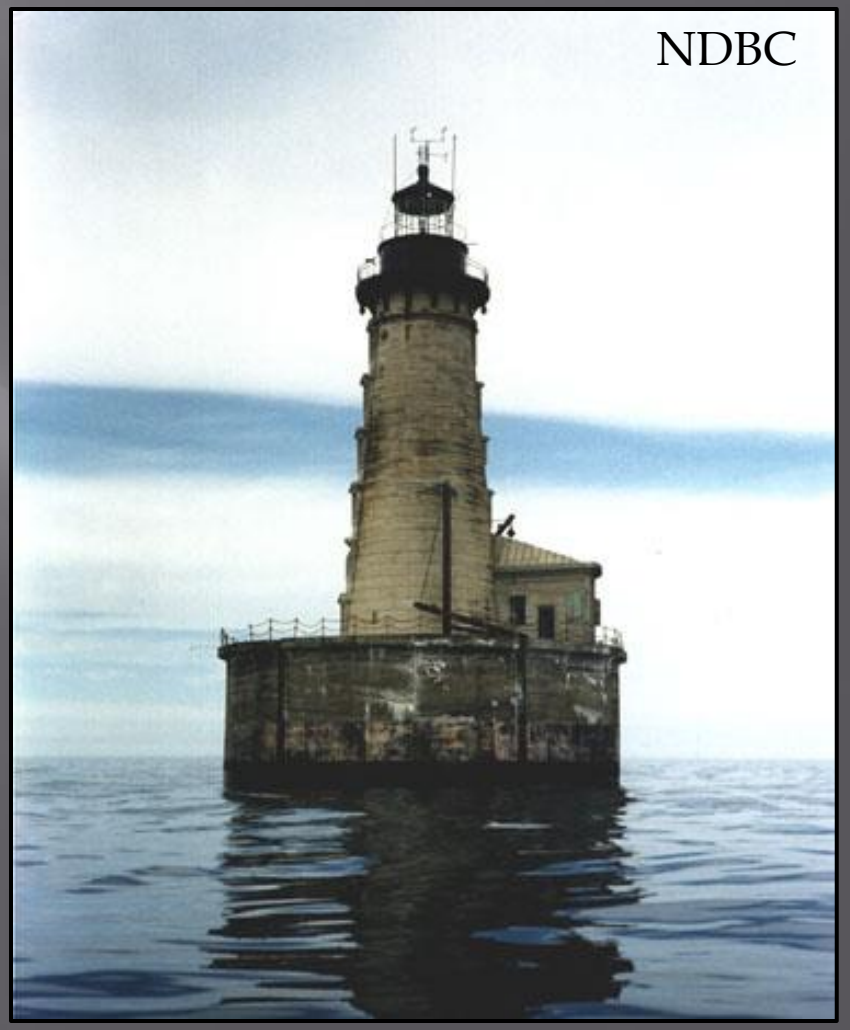
Analysis of High Wind on Lake Superior

- Several C-MAN and land-based stations available during the cool season
  - Data archive is limited (<15 years at most sites)
  - Many locations are influenced by terrain
- Stannard Rock Lighthouse (STDM4)
  - Void of major terrain influences
  - Nearly 30 years of data
  - Two additional sites:
    - Devils Island, WI (DISW3)
    - Rock of Ages, MI (ROAM4)

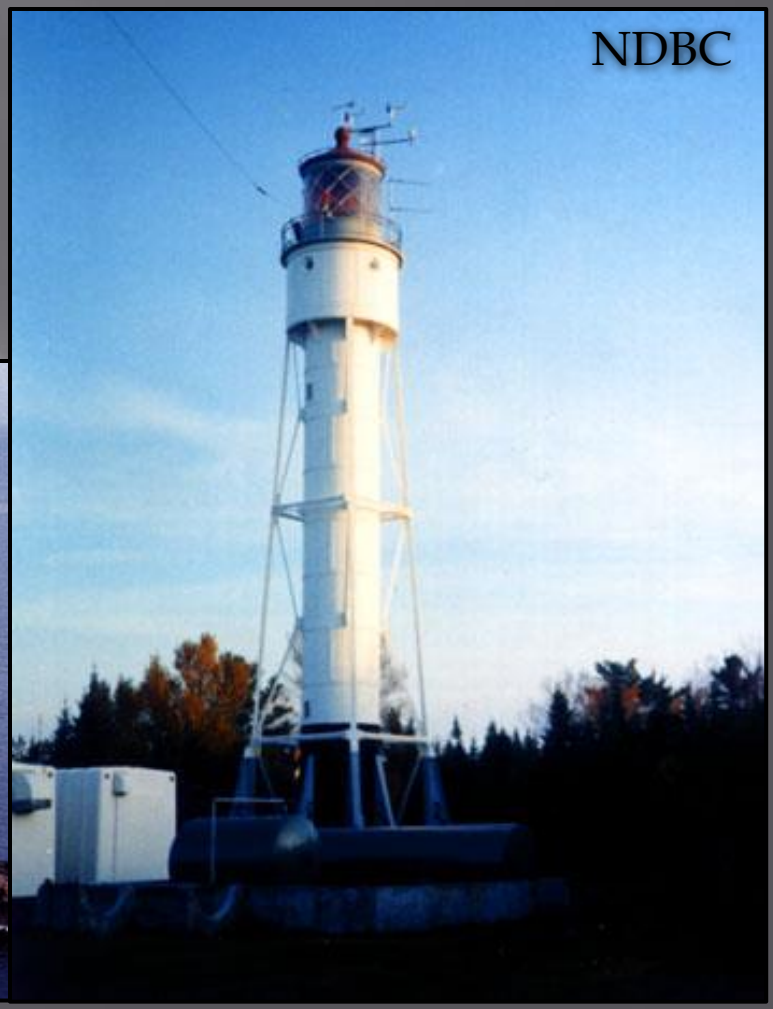
Stannard Rock (STDM4)

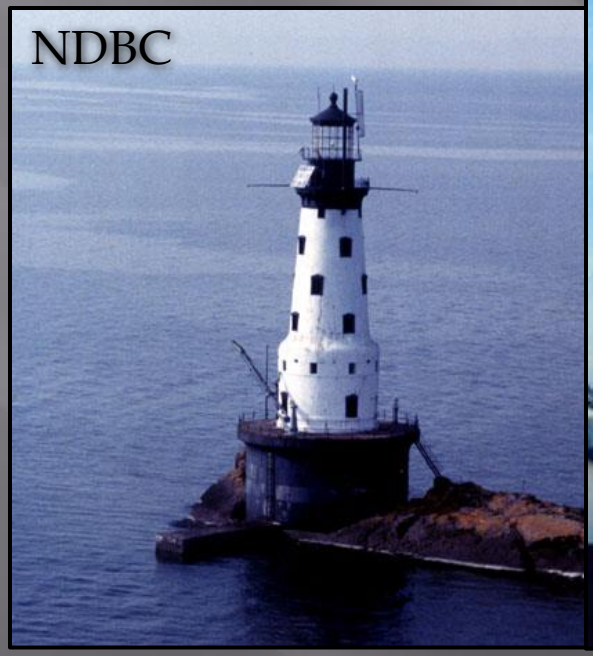
- Data: 7/1984 - present
- Anemometer: 35.2m





- Devils Island (DISW3)
- Data: 10/1983 - present
- Anemometer: 25.3m



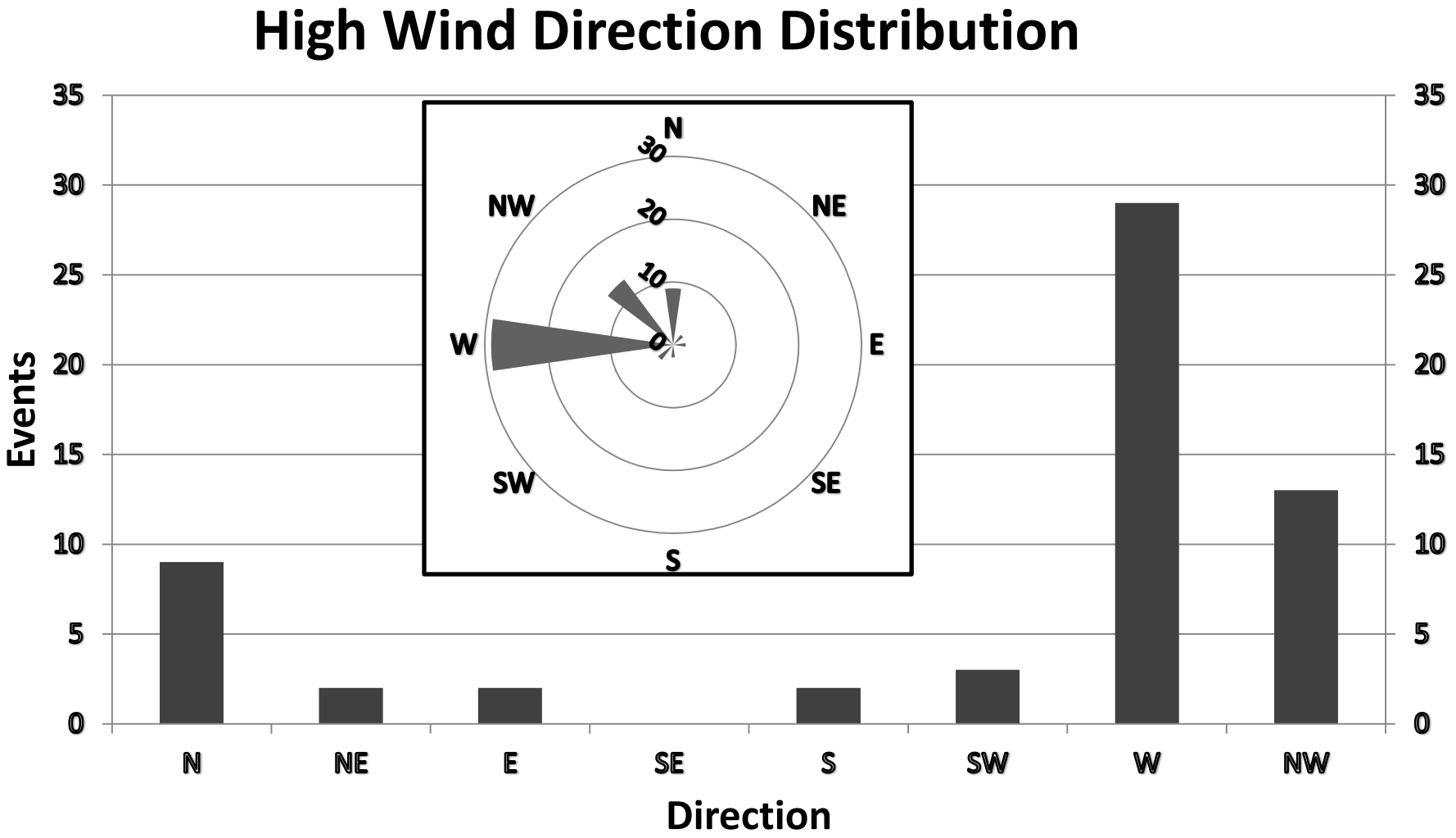


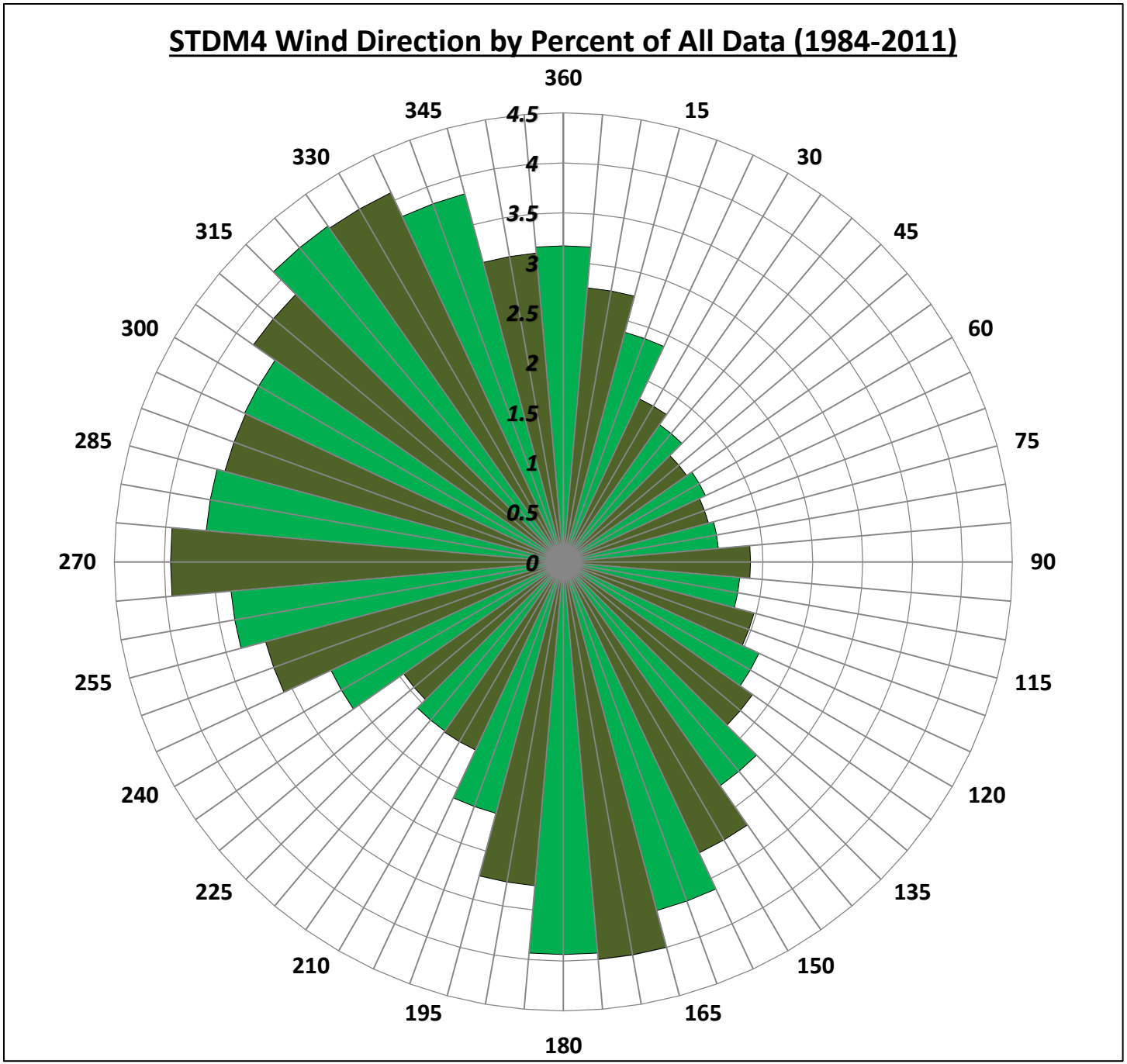
- Rock of Ages (ROAM4)
- Data: 10/1983 – present
- Anemometer: 46.9m

Method

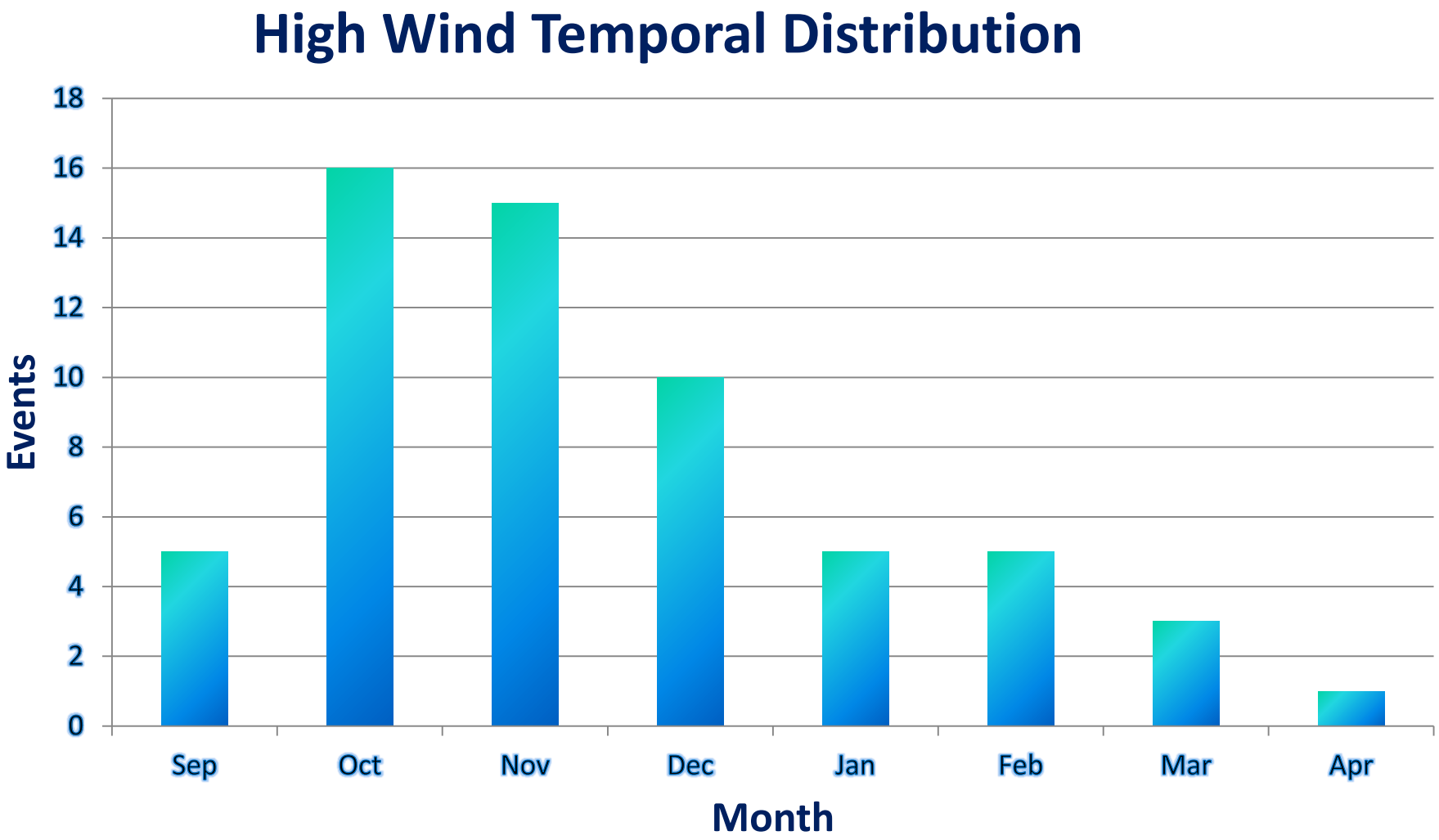
- Hourly data analyzed for the cool season
  - September through April
- A high wind event was noted when wind gusts were ≥ 50kts for at least 3 hourly observations over a 6 hour period (e.g. 53, 49, 54, 50, 48, 55)
- Events with distinct wind shifts (e.g. cold front passage) were broken into separate events
- Number of events:
  - STDM4: 60
  - ROAM4: 9
  - DISW3: 28

Stannard Rock

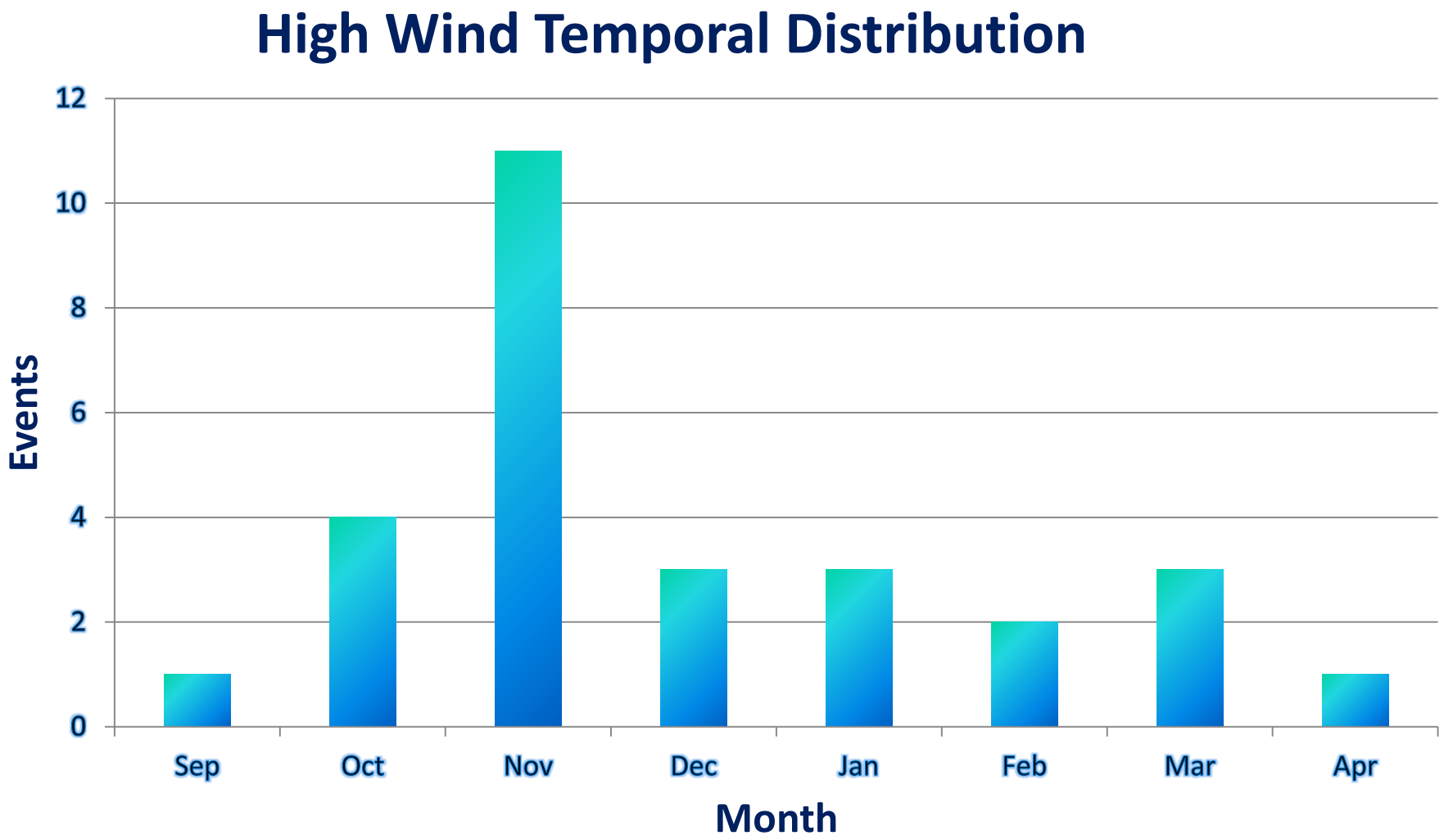



STDM4 Wind Direction by Percent of All Data (1984-2011)
360
15
30
45
60
75
90
115
120
135
150
165
180
195
210
225
240
255
270
285
300
315
330
345
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0

Stannard Rock



Devils Island



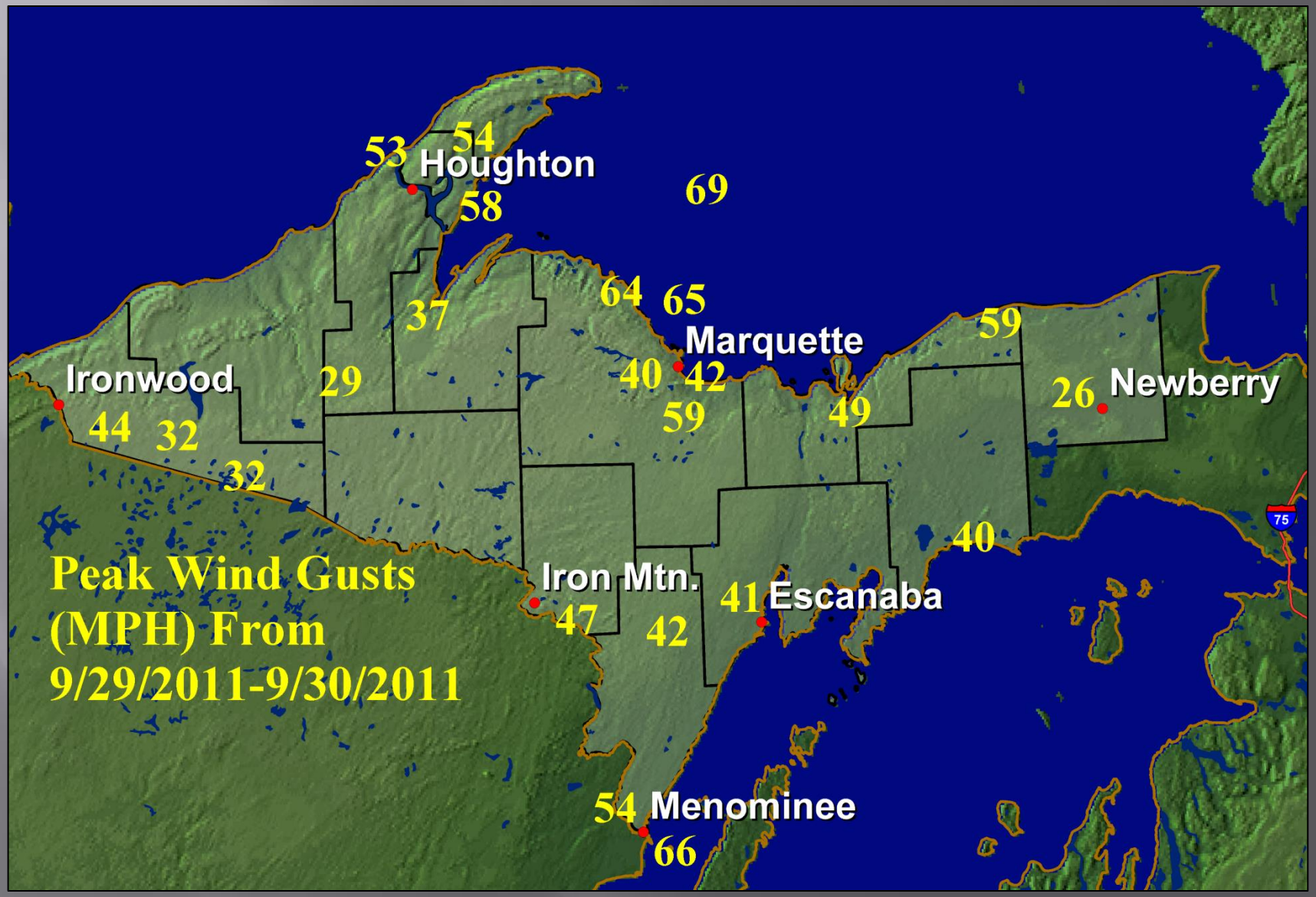
Results – STDM4

- West is the favored direction for high wind events on Lake Superior
  - Slight difference from the WSW direction found by Lacke et al., but similar to the Rochester, MN data
  - Reduced surface friction may result in a slightly veered bias of maximum frequency of direction
- Distinct temporal maximum in the fall (October/November)
- Several September events

Introduction to 9/29/2011 event

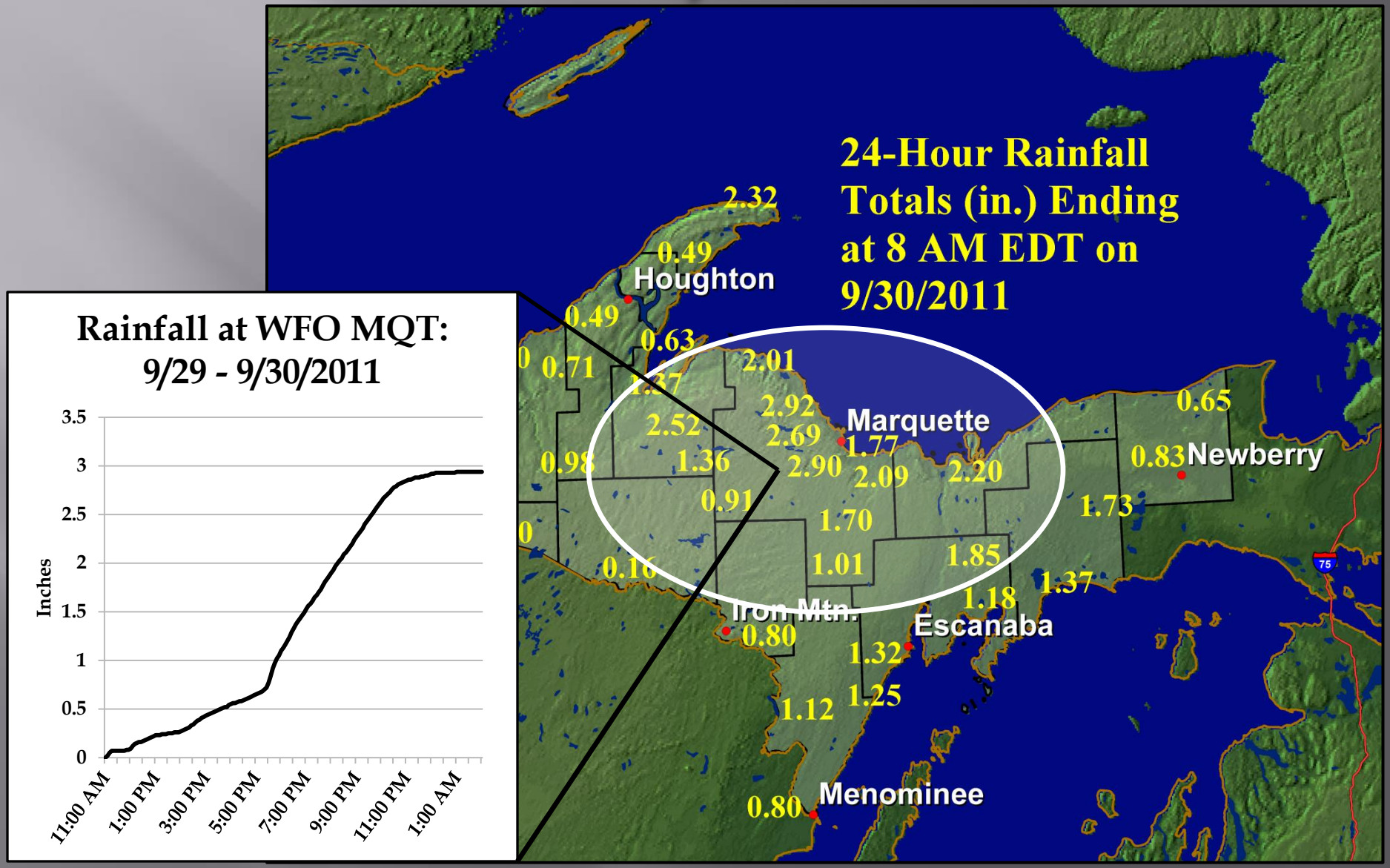
- Quickly evolving early evening event
- Many trees downed along the southern shore of Lake Superior
- Localized pockets of severe wind damage in Marquette County
- Power lost at many locations across northern Upper Michigan
- Heavy rain over a short period of time

Peak Wind Gusts



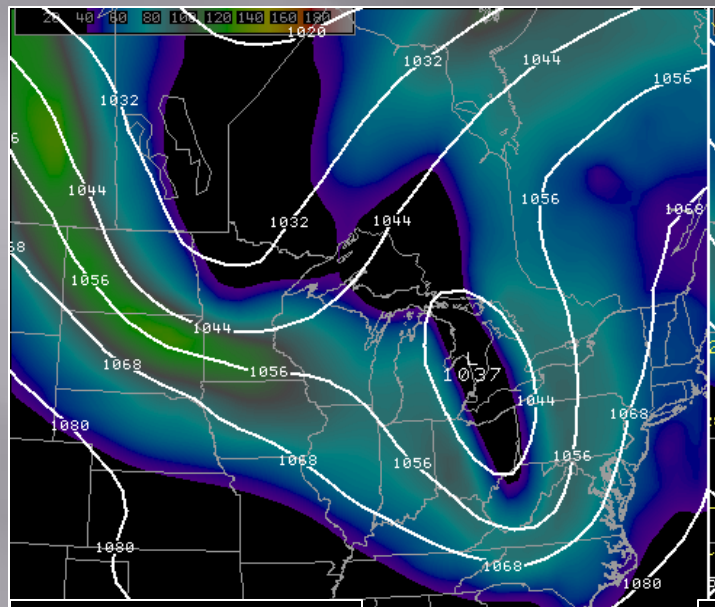
Damage near Marquette

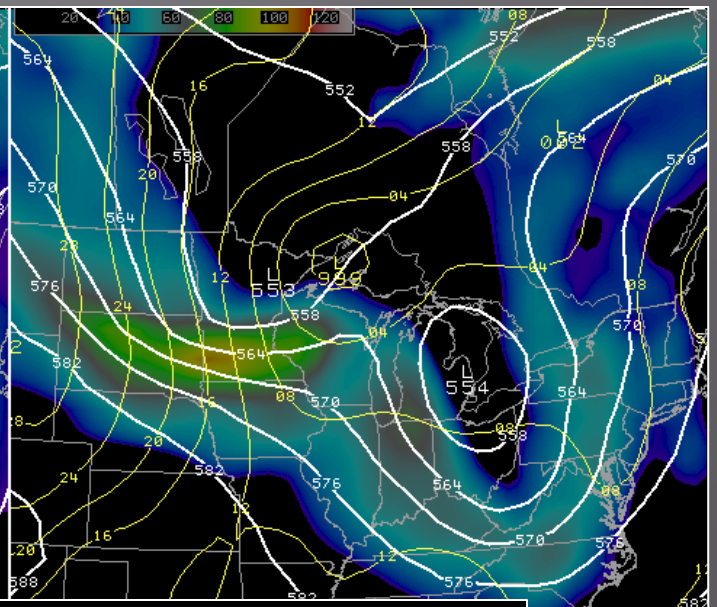
Heavy Rain

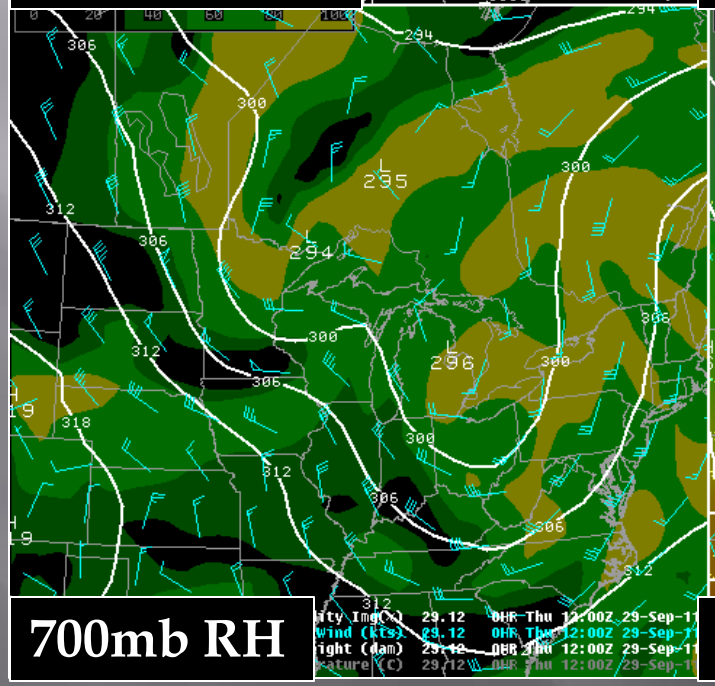

24-Hour Rainfall Totals (in.) Ending at 8 AM EDT on 9/30/2011
Houghton
Marquette
Newberry
Iron Mtn.
Escanaba
Menominee
2.32
0.49
0.49
0.63
0.71
2.01
2.92
2.69
1.77
2.52
1.36
2.90
2.09
2.20
0.98
0.91
1.70
1.01
1.85
0.16
1.37
1.18
0.80
1.32
1.25
1.12
0.80
0.65
0.83
1.73
75
Rainfall at WFO MQT: 9/29 - 9/30/2011
Inches
3.5
3
2.5
2
1.5
1
0.5
0
11:00 AM
1:00 PM
3:00 PM
5:00 PM
7:00 PM
9:00 PM
11:00 PM
1:00 AM

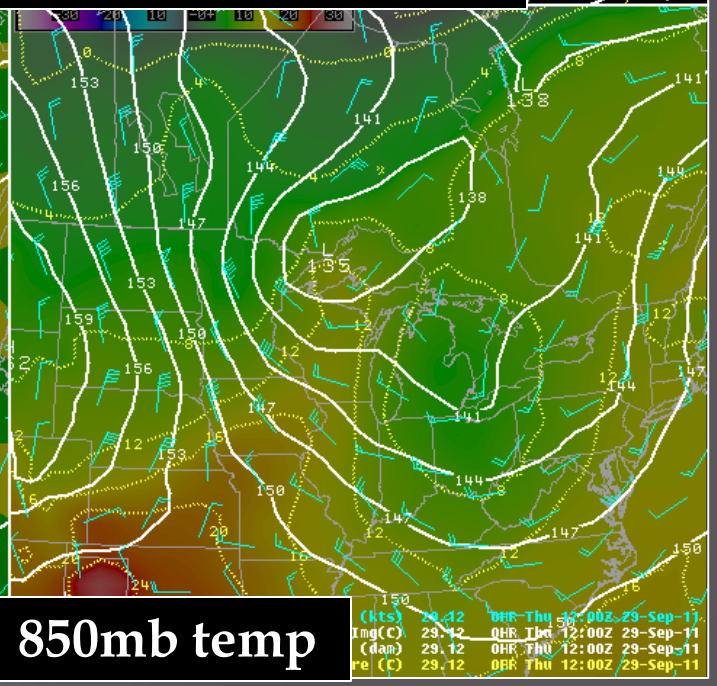
Synoptic Set-up

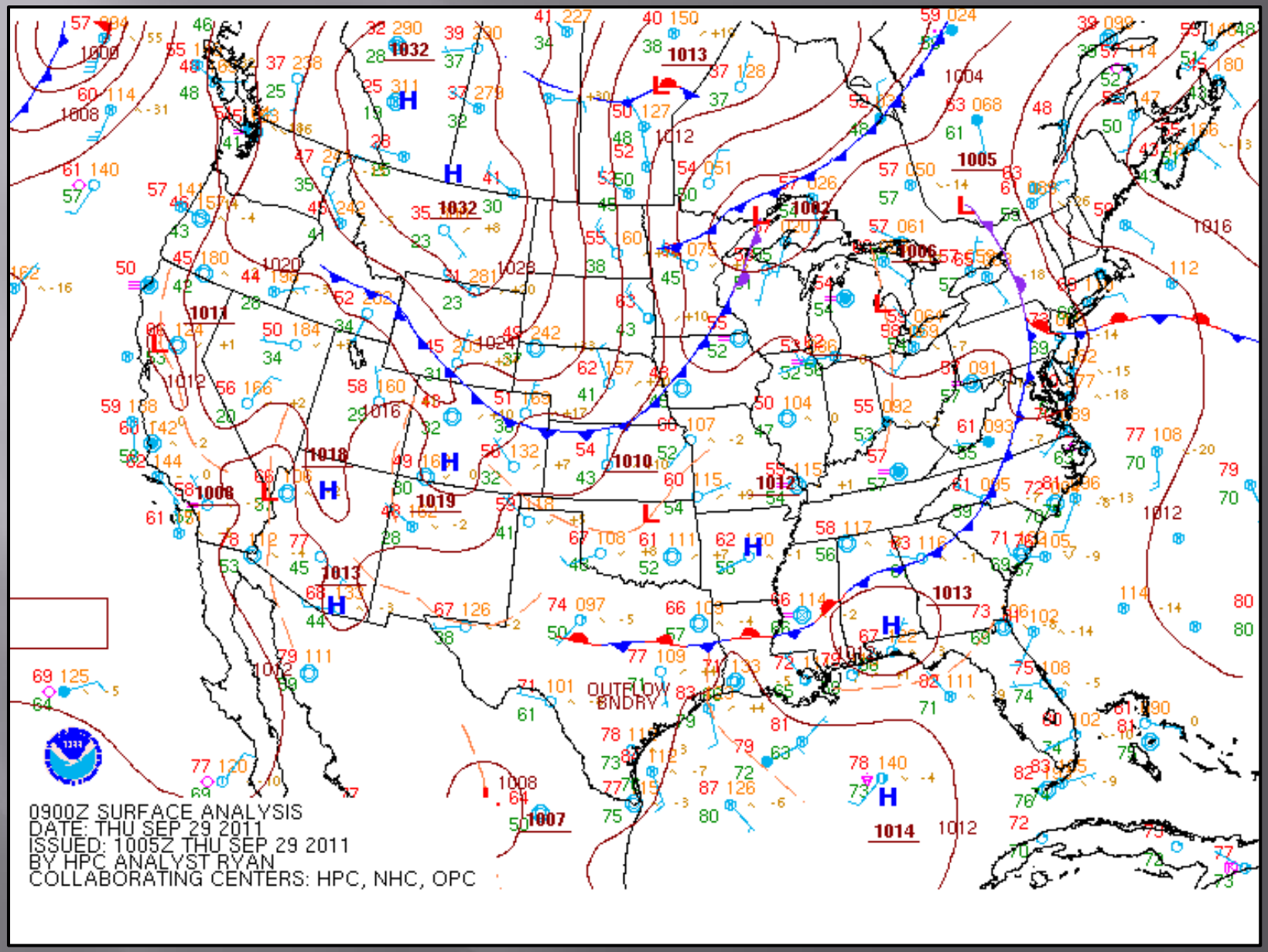
- Compact mid-level shortwave trough moving quickly southeast, passing just south of Upper Michigan
- Weak mid and upper-level winds due to stacked shortwave trough
- Deepening surface low pressure
  - Strengthened 4mb to 992mb over the 6 hours prior to the event
- 1028mb surface high pressure moving into the northern and central Great Plains


250mb wind

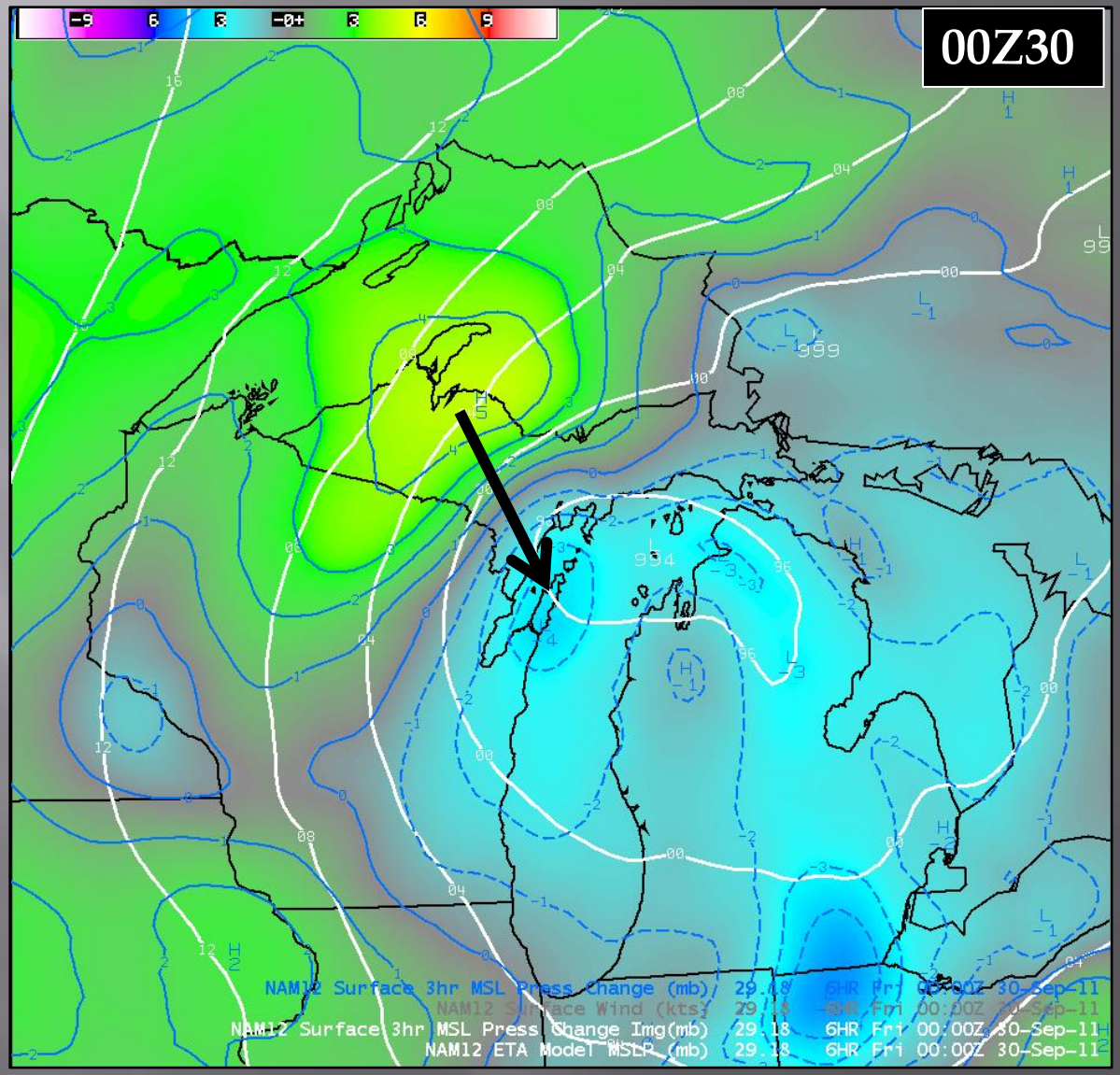

500mb wind; MSLP

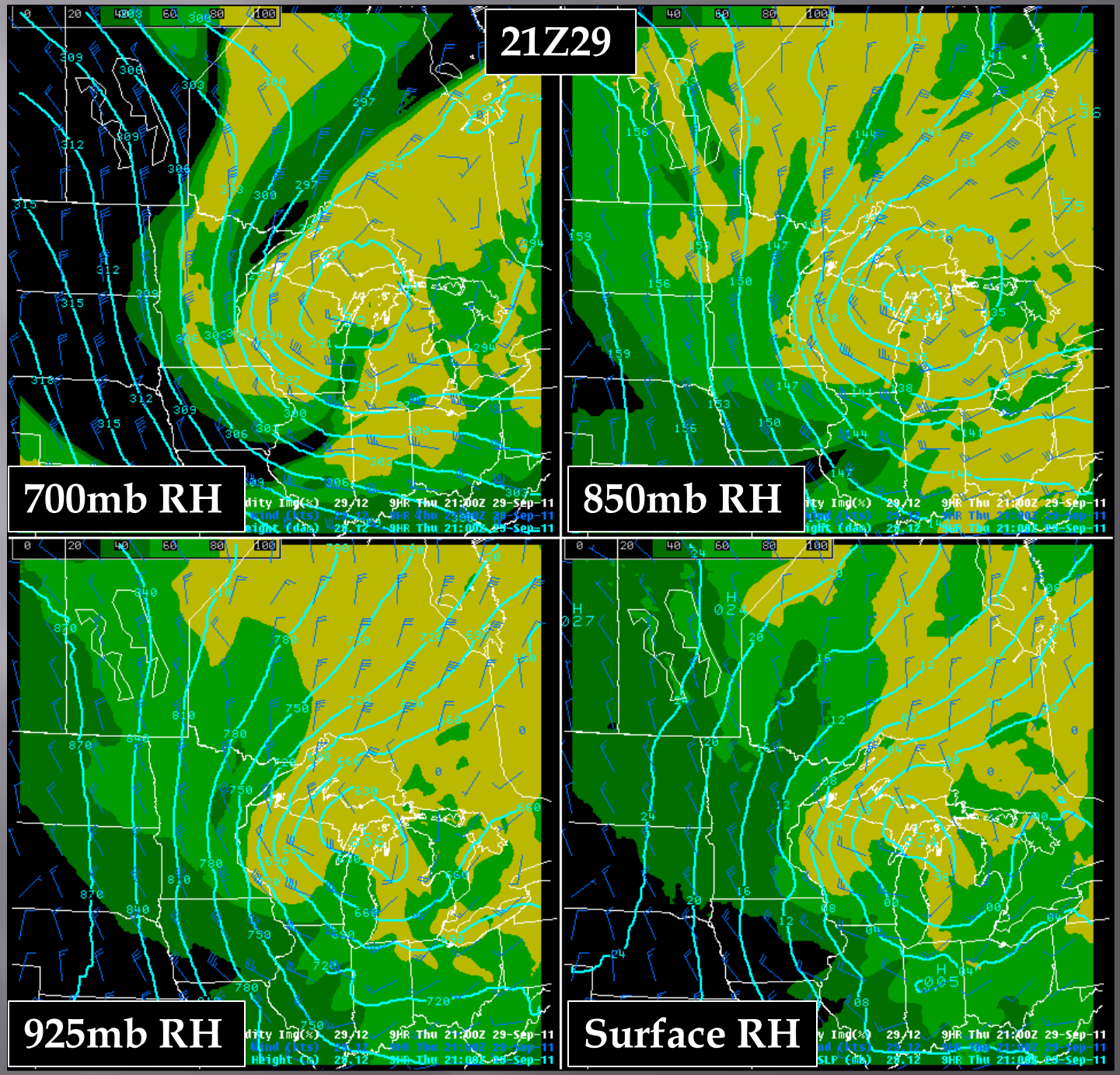

700mb RH

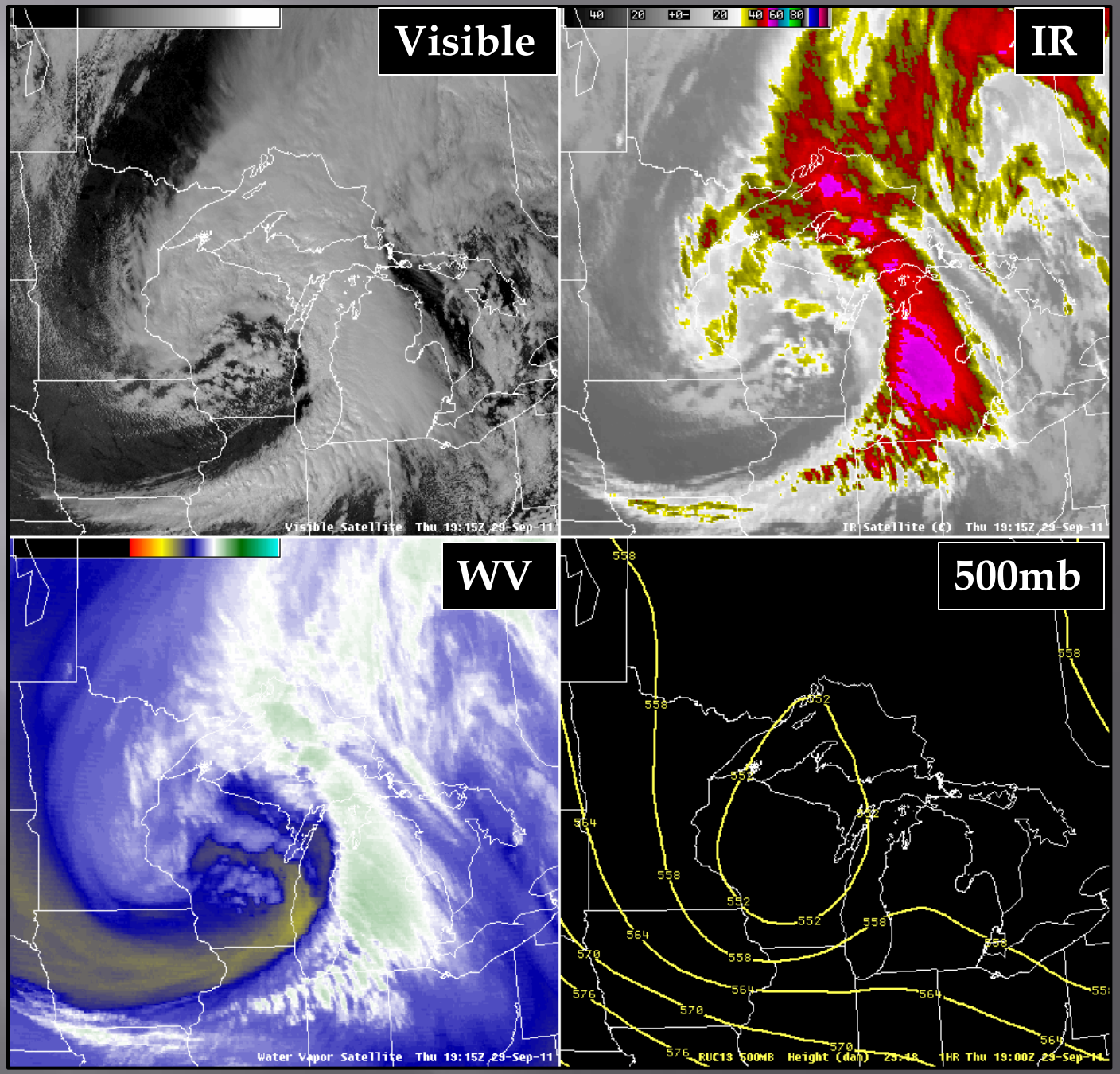

850mb temp


0900Z SURFACE ANALYSIS
DATE: THU SEP 29 2011
ISSUED: 1005Z THU SEP 29 2011
BY HPC ANALYST RYAN
COLLABORATING CENTERS: HPC, NHC, OPC
OUTFLOW
BNDRY

3hr MSLP Change




21Z29
700mb RH
850mb RH
925mb RH
Surface RH

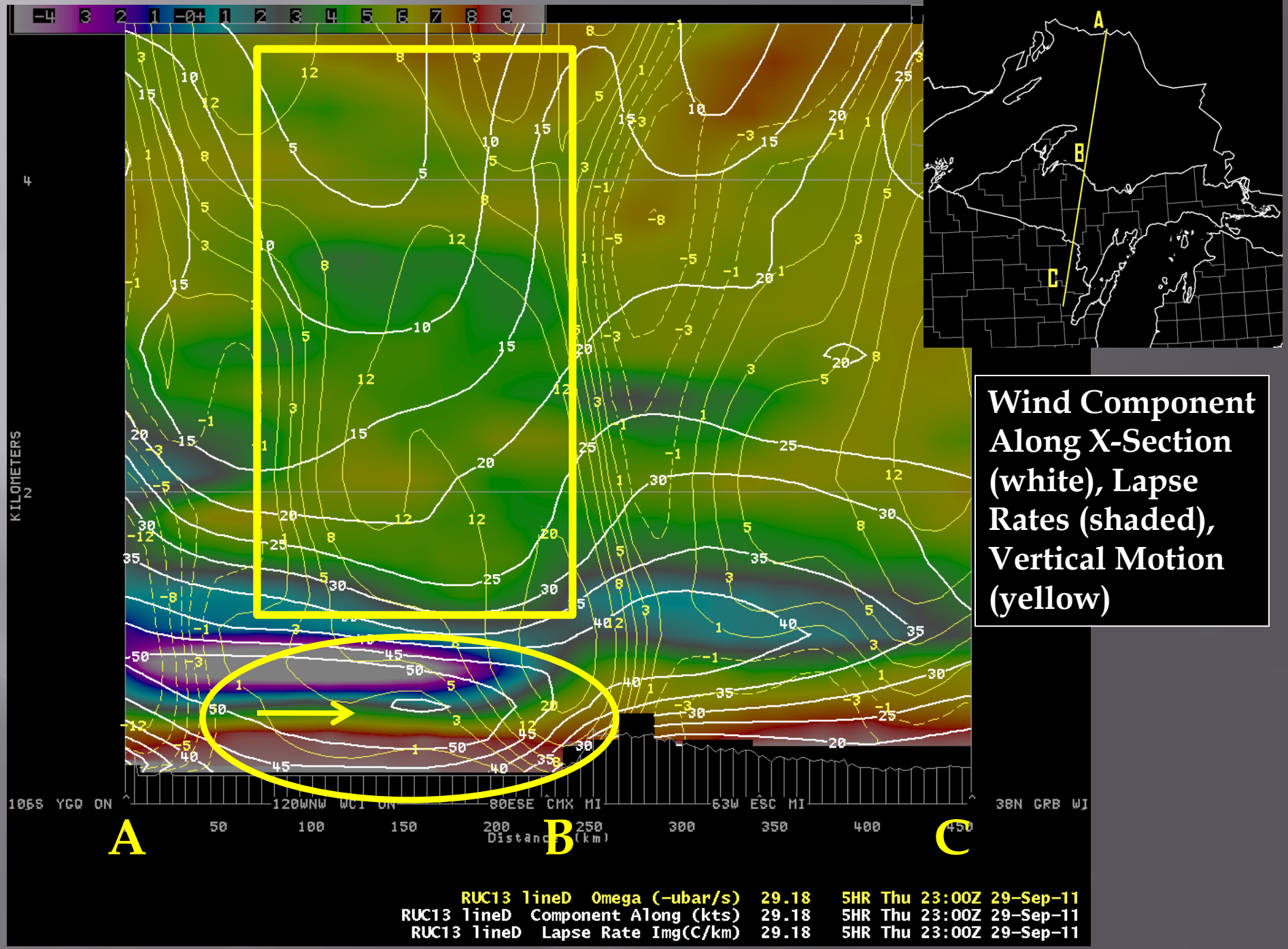

Visible
Visible Satellite Thu 19:15Z 29-Sep-11
IR
40 20 +0- 20 40 60 80
IR Satellite (C) Thu 19:15Z 29-Sep-11
WV
Water Vapor Satellite Thu 19:15Z 29-Sep-11
500mb
558
552
564
570
576
RUC13 500MB Height (dam) 29-48 1HR Thu 19:00Z 29-Sep-11

Why were there high winds?

- Many elements of the Kapela et al. checklist were weak for this event
  - Lack of subsidence
- However, the pressure gradient was very strong
- A key component of the checklist has yet to be mentioned…

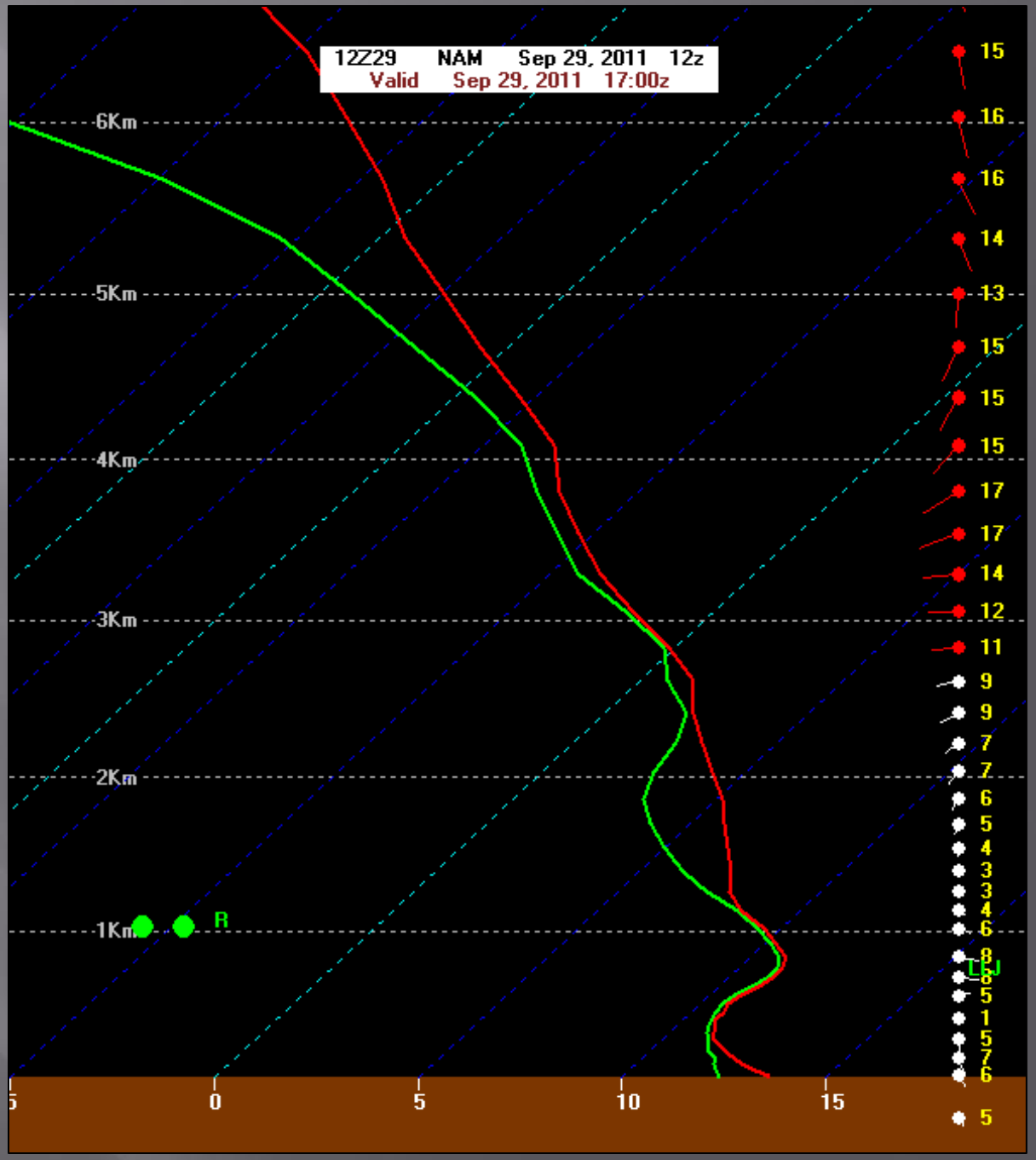
Lapse Rates!

- Lake temperature around 55°F
- High, nearly dry-adibatic lapse rate in the lowest 500m
- Low-level convection?
  - Interesting behavior noticed on the 12Z and 18Z runs of the NAM
  - Possible horizontal convective rolls (HCRs) depicted on radar imagery

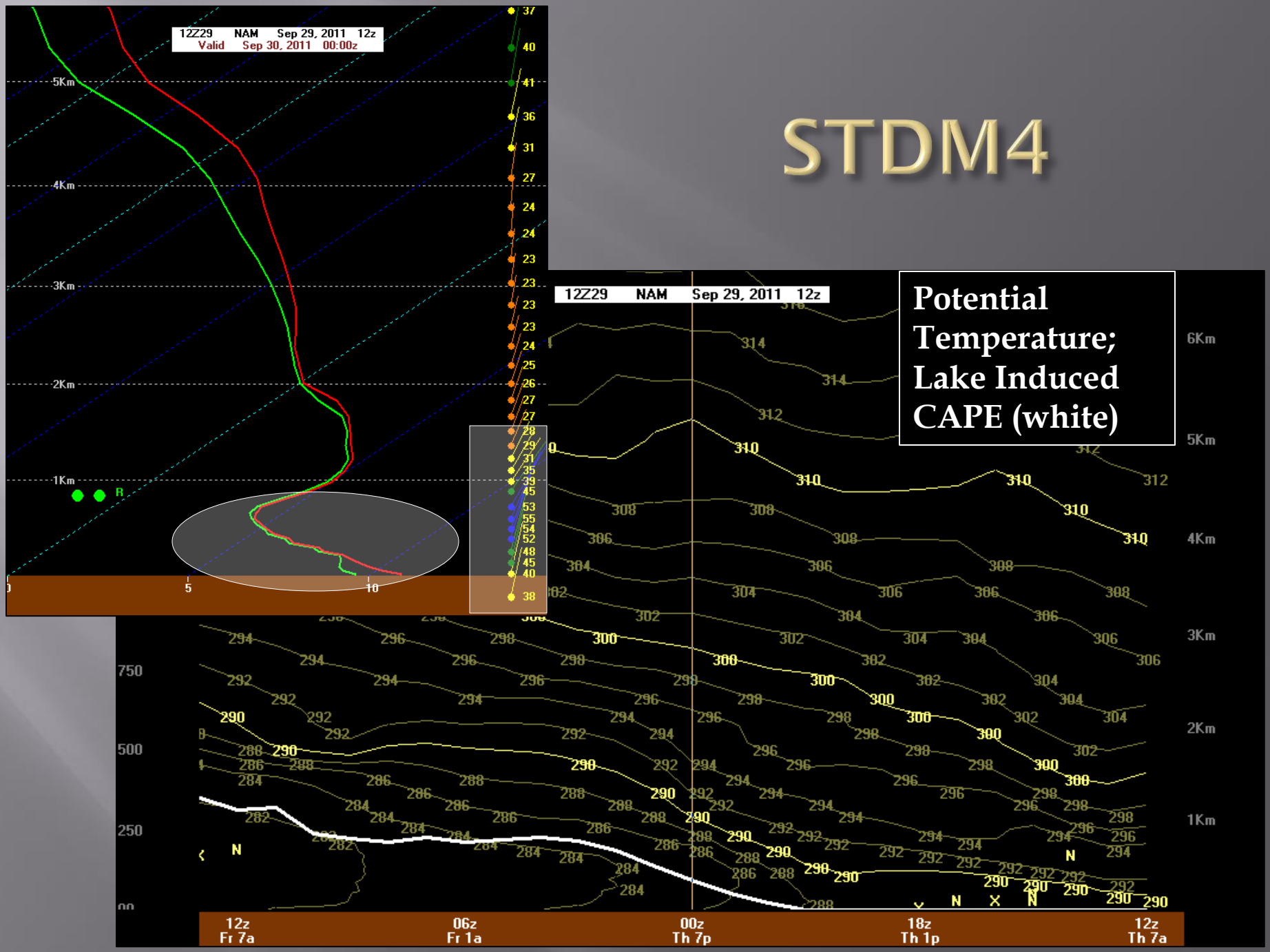


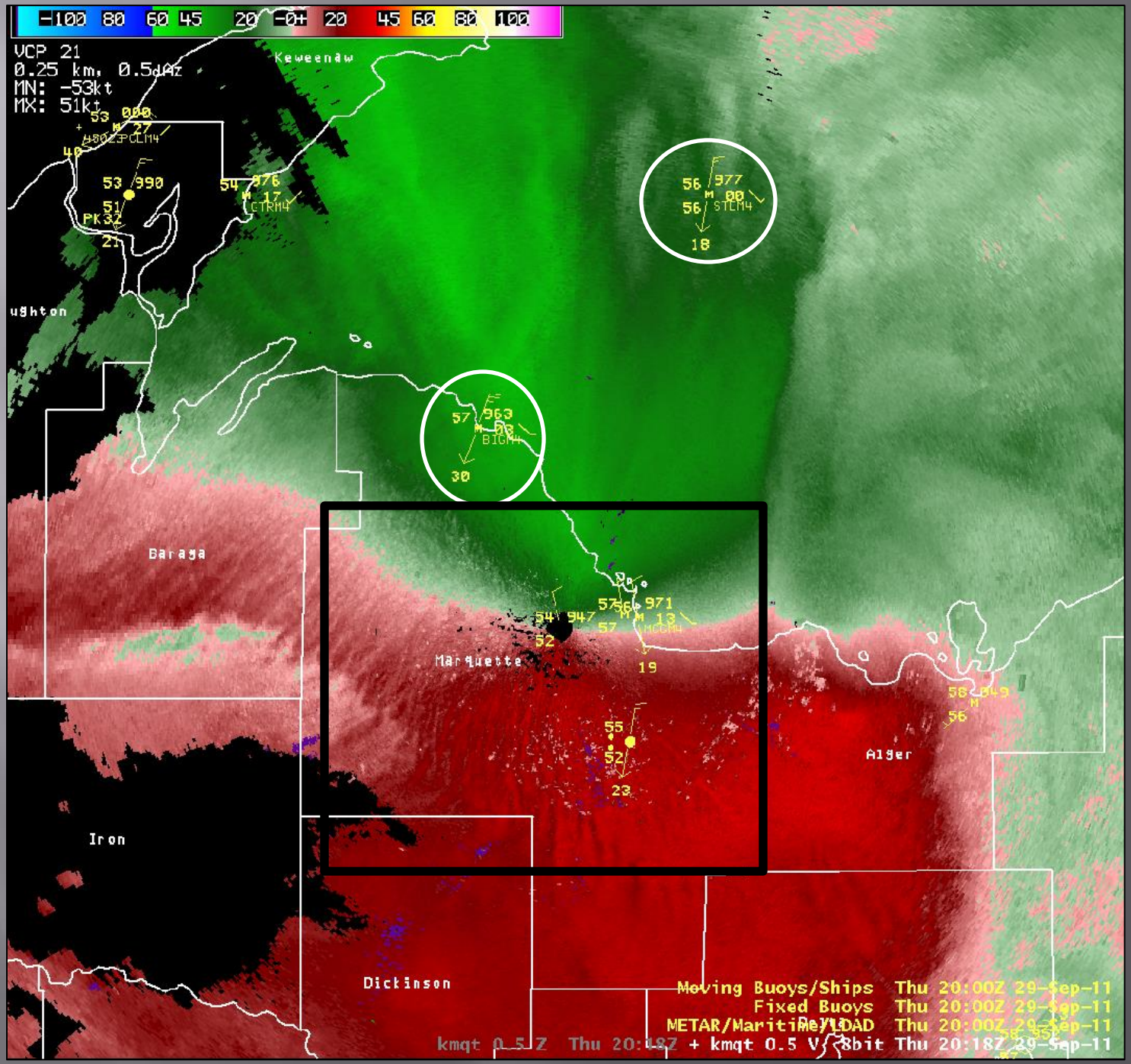
Wind Component Along X-Section (white), Lapse Rates (shaded), Vertical Motion (yellow)

STDM4

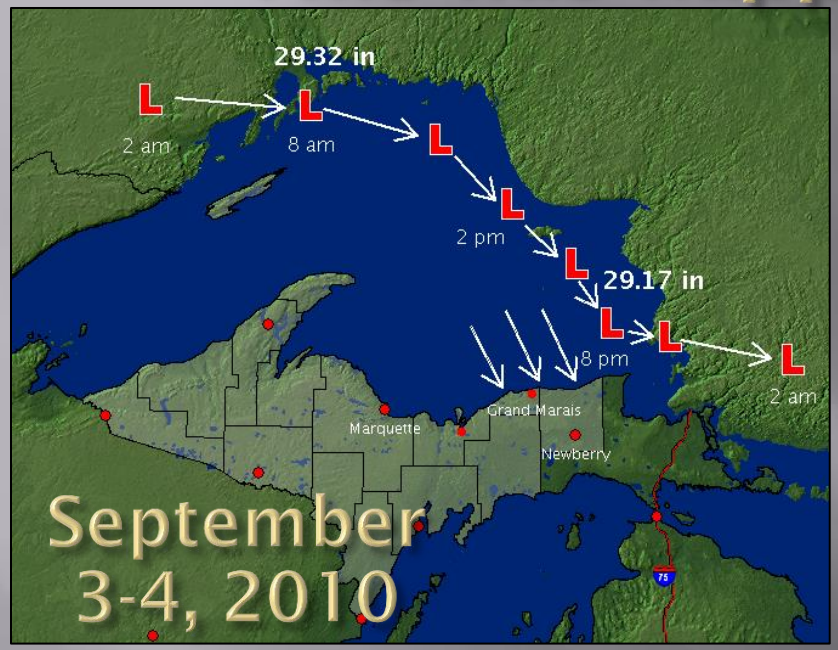

12Z29 NAM Sep 29, 2011 12z
Valid Sep 29, 2011 17:00z
6Km
5Km
4Km
3Km
2Km
1Km
R
15
16
16
14
13
15
15
15
17
17
14
12
11
9
9
7
7
6
5
4
3
3
4
6
8
5
1
5
7
6
5
-5
0
5
10
15

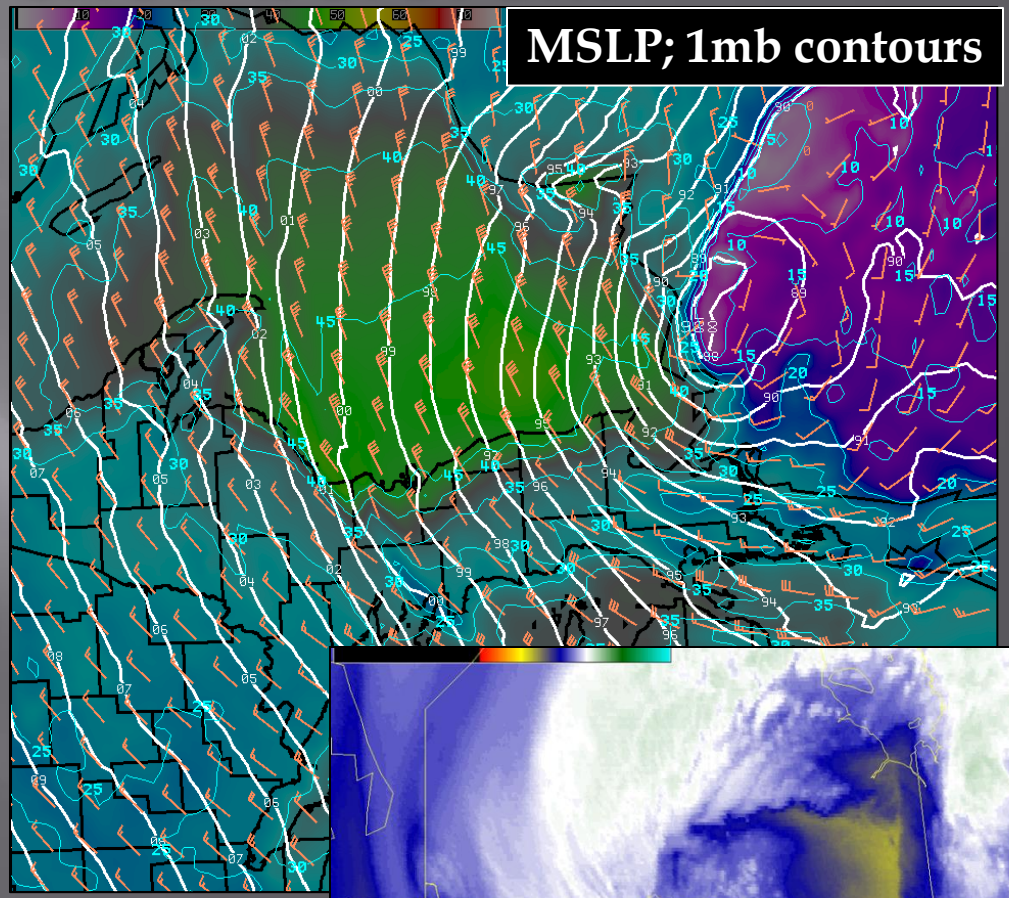
STDM4

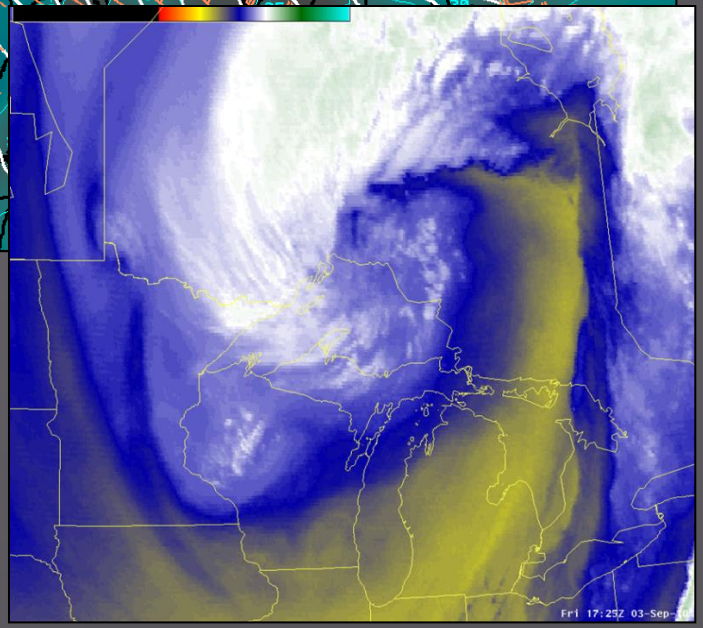

12Z29 NAM Sep 29, 2011 12z
Valid Sep 30, 2011 00:00z
5Km
4Km
3Km
2Km
1Km
12Z29 NAM Sep 29, 2011 12z
Potential Temperature; Lake Induced CAPE (white)
6Km
5Km
4Km
3Km
2Km
1Km
750
500
250
12z Fr 7a
06z Fr 1a
00z Th 7p
18z Th 1p
12z Th 7a


-100 80 60 45 20 -0+ 20 45 60 80 100
VCP 21
0.25 km, 0.5dBZ
MN: -53kt
MX: 51kt
Keweenaw
ughton
Baraga
Marquette
Alger
Iron
Dickinson
Moving Buoys/Ships Thu 20:00Z 29-Sep-11
Fixed Buoys Thu 20:00Z 29-Sep-11
METAR/Maritime/LDAD Thu 20:00Z 29-Sep-11
kmqt 0.5Z Thu 20:18Z + kmqt 0.5 V 8bit Thu 20:18Z 29-Sep-11

This has happened before…

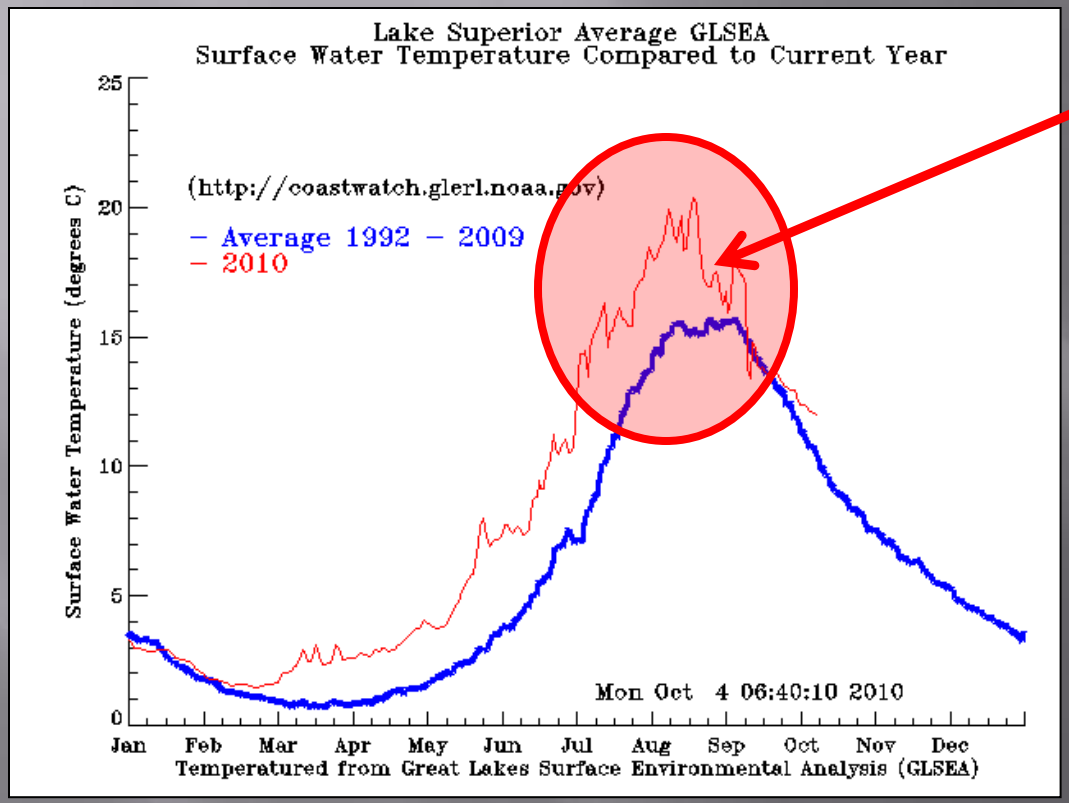






- Stannard Rock – 72 mph
- Grand Marais – 64 mph
- Whitefish Point – 49 mph
- Eastern Buoy – 58 mph
- Caribou Island – 54 mph
- Munising – 54 mph
- *Ore Freighter – 109 mph*
- Record winds and waves for Lake Superior for September

Why did the low stay closer to the lake?



- Water temperatures on Lake Superior were the warmest since 1998
- The "lake aggregate" likely helped to cause a more intense low pressure system

Some Conclusions

- Lake Superior high wind events generally occur from west to west-northwest
- Lake Superior has an earlier peak in high wind episodes than the remainder of the Great Lakes
- Early season events are highly influenced by lake temperatures
  - Do not fit the typical high wind pattern
  - Weak low-level stability is key

Additional Studies

- Do the HCRs lose the ability to mix to the surface over land due to friction and/or stabilization?
- Are these events specific to just Lake Superior?
- How often do these events occur?
- Are a majority of September high wind events driven entirely by weak low-level stability?
  - Were the two September events presented here really anomalous?

Questions?

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Sources

- Kapela, Anton F., Preston W. Leftwich, Richard Van Ess, 1995: Forecasting the impacts of strong wintertime post-cold front winds in the northern plains. *Wea. Forecasting*, 10, 229–244.
- Niziol, T. A., and T. J. Paone, 2000: A climatology of non-convective high wind events in western New York state. NOAA Tech. Memo. NWS ER-91, 36 pp.
- Lacke, Matthew C., John A. Knox, John D. Frye, Alan E. Stewart, Joshua D. Durkee, Christopher M. Fuhrmann, Sarah M. Dillingham, 2007: A climatology of cold-season nonconvective wind events in the great lakes region. *J. Climate*, 20, 6012–6022.